EFFECTS OF BODILY AROUSAL ON DESIRE TO DRINK ALCOHOL AMONG TRAUMA-EXPOSED EMERGING ADULT COLLEGE STUDENTS

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Alcohol consumption on college campuses is a major public health concern, particularly among emerging adults. Extant literature has identified trauma exposure and posttraumatic stress as robust risk factors for problematic alcohol use. However, the mechanisms underlying this association are less well-studied. Research indicates that bodily arousal is a fundamental feature of trauma exposure and posits that internal stimuli (e.g., heart pounding) at the time of trauma may manifest into conditioned cues that can trigger posttraumatic responding and related symptomatology, including alcohol use. However, past work supporting these assertions have used paradigms purposefully designed to evoke memories of the trauma, making it difficult to conclude whether the subsequent alcohol craving was due more to the explicit memory cue or the associated bodily arousal. The current study examined whether an implicit, trauma-relevant cue of bodily arousal (via hyperventilation) – independent of any explicit memory cue – would elicit increased desire to drink among 80 (Mage = 20.34; 63.8% female) trauma-exposed, emerging adult students. Results found no statistically significant difference in change in alcohol craving between the hyperventilation and control tasks. However, exploratory analyses indicated that trauma type (i.e., interpersonal/non-interpersonal) may moderate this relationship; more specifically, individuals reporting interpersonal trauma as their most traumatic event evidenced a significantly greater increase in desire to drink following hyperventilation compared to the non-interpersonal index trauma group. Generally, results suggest that bodily arousal, without an explicit trauma

reminder, is not a specific and/or powerful enough trauma-relevant cue to reliably influence alcohol cravings across all trauma exposed emerging adult students. Suggestions for future directions to help in identifying at-risk subgroups, as well as methodological and procedural improvements, are discussed.

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EFFECTS OF BODILY AROUSAL ON DESIRE TO DRINK ALCOHOL AMONG TRAUMA-EXPOSED EMERGING ADULT COLLEGE STUDENTS

Introduction

Alcohol use is a serious public health concern, playing a critical role in nearly 88,000 deaths per year (Stahre et al., 2014) and costing upwards of $249 billion annually in the United States (Sacks et al., 2015). According to recent adolescent data from the Monitoring the Future study, 35% of 12th grade students reported consuming alcohol in the past 30 days, with 19% endorsing binge drinking (i.e., five or more drinks in a row) in the past two weeks (Johnston et al., 2015). Among adults, these rates are even higher, with 56.4% reporting drinking in the last month and 24.6% endorsing binge drinking (Substance Abuse and Mental Health Services Administration, 2013a). Recent work has further highlighted a period of development in early adulthood (i.e., typically between the ages of 18 and 25) that is theoretically and empirically distinct from both adolescence and general adulthood, and may have particular relevance to the study of alcohol and related problems. Termed “emerging adulthood,” this period is characterized by distinct intrapersonal (e.g., identity development) and interpersonal exploration, newfound personal freedom paired with primarily self-focused responsibility, and an optimism (Arnett, 2000; 2014; Tanner, 2006) reminiscent of the ‘personal fable’ of adolescence (Alberts, Elkind, & Ginsberg, 2007). Consistent with the developmental context of the period, empirical work indicates a peak in the prevalence of daily alcohol consumption, binge drinking, and intoxication (Griffin, 2010), as well as other alcohol-related risky behaviors, such as driving while intoxicated and unprotected sex (Arnett, 2015; Miller, 2012; King, Nguyen, Kosterman, Bailey, & Hawkins, 2012),

among emerging adults. One population encompassed within emerging adulthood that may be at particular risk for problematic alcohol use is college students, as drinking on university campuses has become a normative social phenomenon (Chen & Kandel, 1995; Lee, Geisner, Neighbors, & Patrick, 2010).

Problematic Alcohol Use: Risk Factors among EA College Students

According to the National Survey on Drug Use and Health (SAMHSA, 2013b), approximately 60% of college students reported drinking alcohol, and 40% endorsed binge drinking in the past 30 days (Johnston, O'Malley, Bachman, & Schulenberg, 2011). Further, approximately 18-20% meet criteria for current alcohol use disorder (AUD; Blanco et al., 2008; Slutske, 2005). These prevalence rates not only are markedly higher than the general adult population (e.g., 6.8% current AUD; SAMHSA, 2014a), but are also higher than those found among persons of the same age who are not in college (e.g., up to 15%; SAMHSA, 2014b; 2014c; 2014d; Slutske, 2005). This increase in consumption and binge drinking among emerging adult college students has been linked with a host of negative consequences, including academic problems (Engs, Diebold, & Hansen, 1996; Wechsler et al., 2002), legal issues (Syre, Pesa, & Cockley, 1999; Engs & Hanson, 1994), property damage (Wechsler, Moeykens, Davenport, Castillo, & Hansen, 1995), physical and sexual assault (Hingson, Heeran, Winter, Wechsler, 2005; Kilpatrick, Resnick, Ruggiero, Conoscenti, & Mccauley, 2007), as well as death due to unintentional and intentional injury (e.g., traffic accidents, suicide; National Highway Traffic Safety Administration, 2002; Hingson, Zha, & Weitzman, 2009). For example, data on 41,667 students from 77 institutions found that 15% of

college drinkers reported unintended self-injury because of alcohol use, while 6% endorsed having suicidal ideation; and nearly 2% disclosed that they had attempted to commit suicide while drinking within the last year (Presley, Meilman, Cashin & Lyerla, 1996).

Considering the high prevalence of alcohol use by college students, coupled with the negative consequences resulting from this drinking, a substantial literature has sought to identify potential risk factors for (a) general use of alcohol and binge drinking and (b) the subsequent development of alcohol abuse, dependence, and other related problems (e.g., see Ham & Hope, 2003 for review). For example, increased alcohol use and binge drinking have been linked to several psychosocial factors that may be particularly salient among college students, such as desire for acceptance (Lee et al. 2010), positive alcohol expectancy from drinking (Zamboanga, Schwartz, Ham, Borsari, & Van Tyne, 2010), perceptions of alcohol consequences (Read, Griffin, Wardell, & Ouimette, 2014), willingness to drink (Mallet, Varvil-Weld, Turrisi, & Read, 2011), and peer group associations, such as involvement in Greek organizations or athletics (Wechsler et al, 1995). Drawing from the general adult literature, problematic alcohol use also is associated with several forms of mood and anxiety psychopathology, including major depressive disorder (MDD; Hasin, Goodwin, Stinson, & Grant, 2005), obsessive compulsive disorder (OCD; Manacebo, Grant, Pinto, Eisen, & Rasmussen, 2009), social anxiety disorder (SAD; Allan, 1995; Morris, Stewart, & Ham, 2005), generalized anxiety disorder (GAD; Kessler et al., 1997; Smith & Book, 2010), and panic disorder (PD; Cox, Norton, Swinson, & Endler, 1990; Bunaciu et al., 2010). Within this body of work, one of most consistent and well-studied linkages among adults has

been between problematic alcohol use and traumatic event exposure/ posttraumatic stress disorder (PTSD; see reviews by Stewart, 1996; Debell et al., 2014). National epidemiological studies indicate that upwards of 42-59% of individuals with PTSD in the general population also meet criteria for AUD (Jacobsen, Southwick, & Kosten, 2001; Pietrzak, Goldstein, Southwick, & Grant, 2011), with even higher comorbidity in some specific populations (e.g., 63-75%), such as Vietnam and Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) veterans (Kulka et al., 1990; Seal et al., 2011). Further, research has demonstrated that individuals suffering concurrently from both disorders typically report earlier onset of PTSD symptoms, greater severity of PTSD symptoms, are more likely to have attempted suicide, and struggle more through treatment than individuals with PTSD alone (e.g., slower progress, faster occurrence and higher quantity of relapses; Blanco et al., 2013; Nosen, Littlefield, Schumacher, Stasiewicz, & Coffey, 2014; Ouimette et al., 1999; Read, Brown, & Kahler, 2004). Finally, work examining maintenance of symptoms in PTSD-alcohol dependence (AD) patients found that increases in PTSD symptoms were associated with significant increases in same-day and next-day drinking (Simpson, Stappenbeck, Luterek, Lehavot, & Kaysen, 2014).

Although a substantial literature has examined these associations, there are several consistent limitations marking this work. First, much of this research has used a broad lens when investigating diagnostic co-occurrence and comorbidity in adulthood. More specifically, many studies have used wide cross-sections of participants to examine PTSD-AUD interplay in adulthood – where ‘adults’ are defined simply as ‘over the age of 18’ – ignoring important differences evidenced within varying phases of

adulthood (e.g., psychological characteristics; Pinquart, 2001). For example, in their systematic review of comorbid PTSD-alcohol misuse, Debell and colleagues (2014) referenced several studies where the adult participants' age range spanned nearly five decades (e.g., Johnson, Cottler, O'Leary, & Abdallah, 2010), and other studies that included both adolescent and geriatric populations within their samples (e.g., 15-80 years old; Blume, Resor, Villanueva, & Braddy, 2009). Second, much of the PTSD-AUD literature, particularly laboratory-based (e.g., Hopper, Frewen, van der Kolk, & Lanius, 2007) and intervention- or treatment-focused work (e.g., Ramchand, Rudavsky, Grant, Tanielian, & Jaycox, 2015; Roberts, Roberts, Jones, & Bisson, 2015), has targeted clinical and/or military populations. While this research is critical to understanding the interplay between posttraumatic stress and alcohol use within these high-risk populations, the risk factors and underlying mechanisms identified cannot be assumed to exist, or function in the same way, in other populations. Notably, no laboratory-based work has examined these associations specifically among emerging adult college students, and none have employed the experimental psychopathology techniques necessary to extrapolate preliminary causal inferences.

Trauma, Posttraumatic Stress, and Alcohol among EA College Students

Examining trauma exposure and posttraumatic stress as a risk factor for the development of problematic alcohol use may be particularly meaningful among emerging adult college students for at least three reasons. First, research indicates high prevalence of exposure to trauma among college students, with upwards of 66-85% of students reporting experiencing a lifetime traumatic event, as defined by the *Diagnostic*

and Statistical Manual – 4th Edition (*DSM-IV*; APA, 2000; Elhai et al., 2012; Frazier, 2009; Read, Ouimette, White, Colder, & Farrow, 2011). Second, rates of current PTSD are estimated to be as high as 9% among emerging adult college students (McDevitt-Murphy, Weathers, Flood, Eakin, & Benson 2007; Read et al., 2011; Smyth, Hockemeyer, Heron, Wonderlich, & Pennebaker, 2008), which is substantively higher than estimated prevalence in the general adult population (e.g., 3.5%; Kessler, Chiu, Demler, Merikangas, & Walters, 2005). Third, for many emerging adults, college may be their first experience with navigating stress on their own, away from family and established friendships (e.g., Arnett, 2000). Unfortunately, this newfound independence coincides with a period of heightened instability (e.g., shifting friendships, romantic partners; Shulman & Connolly, 2013). Given that emerging adults are still developing their identity (e.g., habit-building; Luyckx, Goossens, & Soenens, 2006), this instability can undermine the development of healthy coping strategies (e.g., seeking social support; Zaleski, Levey-Thors, & Schiaffino, 1998). Coupled with the access and availability of alcohol on college campuses, as well as the normalization of use (Lee et al., 2011), this may put these emerging adult college students at particular risk for using alcohol as a means of coping with stress and posttraumatic responding. However, despite theoretical and empirical work demonstrating that emerging adult college students are (a) at greater risk for exposure to trauma (e.g., Frazier et al., 2009) and the development of posttraumatic stress symptomatology (e.g., Read et al., 2012), (b) in a period where cognitive and behavioral patterns (e.g., coping strategies; Zaleski et al., 1998) are still being developed and refined, and (c) at greater risk for the problematic

use of alcohol (e.g., Griffin, 2010), limited work has examined the influence of trauma exposure and posttraumatic stress on alcohol use in this population.

Findings from the growing correlational literature examining college students are largely consistent with the data collected in general adult samples, with emerging adult college students who are exposed to trauma (both with and without PTSD) being at significantly greater risk for problematic alcohol use than students not exposed to trauma (Twamley, Hami, & Stein, 2004). Several studies have employed intensive, short-term (e.g., daily dairy) and prospective, longitudinal assessments of these associations to more closely and reliably examine temporal patterns (e.g., Kaysen et al., 2014; Read et al., 2012). Of note, this work does indicate that increases in alcohol use are associated with elevated risk of (re-)experiencing a trauma (e.g., revictimization; Messman-Moore, Ward, and Brown, 2009). In fact, incidence of trauma in a context involving alcohol use are distinctly high among emerging adult college students, such as motor vehicle collisions due to drunk driving (Arnett, 2015; NHTSA, 2002) and alcohol-related sexual assault and rape (Abbey, McAuslan, Zawacki, Clinton, & Buck 2001; Kilpatrick et al., 2007; Testa, Livingston, Vanzile-Tamsen, & Frone, 2003). However, most of this work has instead supported either a self-medication or mutual maintain model of development between posttraumatic stress and the problematic use of alcohol. In the context of PTSD-AUD, the self-medication model asserts that individuals use alcohol as a means of coping with posttraumatic stress (e.g., Khantzian, 1997). For example, a study of 318 female undergraduates found that a history of sexual assault was associated with increase psychological distress, which contributed to the use of alcohol use as a means of negative reinforcement (Miranda, Meyerson, Long, Marx, & Simpson, 2002).

Alternatively, the mutual maintenance model purports a reflexive relationship between the two conditions, whereby trauma exposure and subsequent posttraumatic stress symptoms lead to alcohol use, which, in turn, leads to maintenance or exacerbation of symptoms (Read et al., 2014). For example, a three-year longitudinal study by Read and colleagues (2014) found a reciprocal relationship between posttraumatic stress symptoms and alcohol consequences, and posited that these alcohol consequences exacerbate posttraumatic stress symptoms over time through promoting maladaptive coping strategies (e.g., continued alcohol use).

Preliminary work has identified several perceptual and psychosocial variables that may serve as risk markers or potential mechanisms (e.g., mediators) in the relationship between posttraumatic stress and alcohol use among emerging adult college students, including affect (Kaysen et al., 2014), alcohol consequences (Bachrach & Read, 2012; Read et al., 2012), alcohol expectancies (Tuliao, Jaffe, & McChargue, 2016), distress tolerance (Dvorak, Arens, Kuvaas, Williams, & Kilwein, 2013), disconstraint (Read, Merrill, Griffin, Bachrach, & Khan, 2014), emotion dysregulation (Klanecky, McChargue, & Tuliao, 2016; Klanecky, Woolman, & Becker, 2015), and maladaptive coping (Bedard-Gilligan, Cronce, Lehavot, Blayney, & Kaysen, 2014). While these preliminary findings critically highlight the need to examine the association between posttraumatic stress and alcohol use specifically among emerging adult college students, the extant literature has relied almost exclusively on cross-sectional (e.g., Dvorak et al., 2013; Klanecky et al., 2016; Smith, Davis, & Fricker-Elhai, 2004) and/or retrospective self-report of symptoms and behaviors (e.g., Read et al., 2014; Woolman, Becker, & Klanecky, 2015). However, understanding the underlying

mechanisms driving the trauma-alcohol use relationship among emerging adult college students is critical to improving the efficacy of prevention and treatment efforts.

Exposure to Bodily Arousal as a Risk Factor for Alcohol Use

Bodily arousal is a fundamental feature of trauma exposure (Nixon & Byrant, 2003; Young, 1996), and theoretical work posits that internal stimuli (e.g., elevated heart rate) at the time of trauma exposure may manifest into conditioned cues that can later trigger posttraumatic stress responding and related symptomatology (e.g., exaggerated startle response, panic; Bedard-Gilligan & Zoellner, 2008; Falsetti, Resnick, Dansky, Lydiard, & Kilpatrick, 1995; Shalev et al., 1998). Self-reported experiencing of intense physiological symptoms by PTSD patients when re-experiencing a traumatic event provides some anecdotal support for conditioned responding (e.g., Ehlers, Hackmann, & Michael, 2004). Further, empirical research examining psychophysiological risk factors also supports these associations, highlighting the prevalence and predictive influence of exaggerated or increased sensitivity to bodily arousal on the development of PTSD and treatment outcomes (see Pitman et al., 2012 for review). In fact, a recent meta-analysis of 122 psychophysiological studies of posttraumatic stress found that several forms of bodily arousal (e.g., skin conductance, elevated heart rate) were robust correlates of PTSD, concluding that increases in psychophysiology were associated with posttraumatic stress (Pole, 2007). Notably, the majority of these studies were conducted with middle-aged male combat veterans.

Other work has suggested that individuals with PTSD are generally anxious or fearful of bodily arousal (Cougle et al., 2010; Jones & Barlow, 1990; Lang, Kennedy, & Stein, 2002). An inherent desire to evade symptoms manifesting from this unwanted

bodily arousal set the foundation for the self-medication model of maladaptive coping—specifically, that individuals use alcohol as a means of coping with distress (e.g., physiological or psychological), which in the absence of other adaptive coping mechanisms (e.g., emotional self-regulation; Ford & Russo, 2006) may eventually develop into problematic alcohol use behaviors and AUD (Khantzian, 1997, 2003). For example, a study by Sinha and colleagues (2009) of adult social drinkers found that participants indicated greater bodily arousal in response to a personalized trauma-relevant stressor (as compared to alcohol-related cue and neutral-relaxing situation) and subsequently indicated greater alcohol craving elicited by the trauma-relevant stressor. Indeed, much of the early work examining this pathway of development has implicated arousal symptoms as the strongest and most consistent correlate of substance use outcomes (Bremner, Southwick, Darnell, & Charney. 1996; McFall, Mackay, & Donovan, 1992; Stewart, Pihl, Conrod, & Dongier, 1998), which suggests that individuals may use alcohol and other substances with anxiolytic properties to control symptoms of hyperarousal (e.g., exaggerated startle response).

More recent laboratory-based work supports these findings, demonstrating that trauma-relevant cues (e.g., via script-driven imagery) can elicit increased desire to drink alcohol (Chaplin, Hong, Bergquist, & Sinha, 2008; Chaplin et al., 2010; Coffey et al., 2002; Coffey, Staiewicz, Hughes, & Brimo, 2006; Coffey et. al, 2010; Conrod & Stewart, 2003; Saladin et al., 2003; Sinha et al., 2009). For example, Coffey and colleagues (2010) found that trauma-relevant cues elicited increases in self-reported craving and distress among patients with comorbid PTSD-AD. Collectively, these theoretical works and observed findings suggest that bodily arousal is an important factor in the

development and maintenance of PTSD, and may present a trauma-relevant cue that can elicit increased desire to drink; this association may be important for prevention and early intervention, as alcohol cravings have evidenced empirical (e.g., Casey, Adamson, Shevlin, & McKinney, 2012; MacKillop et al., 2010) and biological (e.g., Park et al., 2007) links to increases in problematic alcohol use behaviors and onset of AUD.

Voluntary Hyperventilation as a Trauma Cue

Extant literature has demonstrated several trauma-relevant cues effective in eliciting bodily arousal. Much of the research targeting trauma-exposed adults (and the influence of trauma cues on desire to drink) has utilized guided or script-driven imagery, whereby participants vividly describe their worst trauma from the first-person perspective and then are guided through 're-experiencing' the memory of that event with a researcher (e.g., Coffey et al., 2010). The foundational theory and practical implementation of script-driven imagery is explicitly designed to have the participant re-experience the traumatic event, which in turn has been shown to both evoke physiological arousal (e.g., Pitman et al., 2012) and increase craving and desire to drink (e.g., Sinha et al., 2009). However, this methodological approach may inherently limit identifying and interpreting the underlying mechanism(s) driving these psychological and physiological changes. More specifically: Is the elevated responding (e.g., increased desire to drink) due more to the explicit re-experiencing symptomatology evoked by guided recall of the trauma, or more so due to the underlying arousal symptoms cued by that re-experiencing? Further, can bodily arousal, independent of

explicit reminders of the traumatic event, evoke an increase in alcohol craving among trauma-exposed individuals?

Alternatively, other research, typically targeting panic disorder (PD), has used a voluntary hyperventilation challenge as a means of evoking physiological arousal, whereby participants are guided through a hyperventilation task involving breathing at a rate of 30 respiration cycles per minute (Hornsveld, Garssen, & van Spiegel, 1995). Similar to script-driven imagery, empirical work indicates that the voluntary hyperventilation challenge elicits both bodily arousal (e.g., Feldner, Vujanovic, Gibson, & Zvolensky, 2008) and memories of the traumatic event (i.e. re-experiencing; Nixon & Bryant, 2005; Wald & Taylor, 2007; 2008). However, unlike script-driven imagery, the voluntary hyperventilation challenge may serve as an implicit trauma-relevant cue, mimicking conditioned interoceptive cues (e.g., elevated heart rate) from the traumatic event that can subsequently trigger posttraumatic stress-related symptomatology and memories (Bedard-Gilligan & Zoellner, 2008; Falsetti et al., 1995) and lead to increased desire to drink. Given the focus within the current study on bodily arousal as the targeted mechanism, as opposed to re-experiencing via explicit reminders of the traumatic event, use of the voluntary hyperventilation challenge may help to better identify if physiological changes are the underlying mechanism(s) driving participants' desire to drink.

In addition to postulated theoretical advantages, the voluntary hyperventilation challenge also was chosen as the trauma-relevant cue in the current study for several methodological reasons. First, the challenge allows for standardization across participants, as well as the use of a standardized comparator—more specifically, all

participants will get the same instructions and perform the same task(s) for the same amount of time. Second, unlike script-driven imagery, voluntary hyperventilation is not plagued by affective, attentional, or recall biases (e.g., Wright & Morley, 1995), and though voluntary, is less amenable to avoidance strategies that may impact the overall effect of the manipulation. Third, the nature of the challenge should limit any adverse physiological or psychological events resulting from the task (i.e., participants can stop the task at any moment, with the physiological effect dissipating within minutes). Lastly, treatment-focused work has demonstrated that individuals with more severe trauma symptomatology may be easily overwhelmed by explicit re-exposure to trauma (Coffey, Dansky, & Brady, 2003), which has prompted clinicians to begin to develop treatments that keep participants "in the moment" (e.g., Safety Seeking; Najavits, Schmitz, Gotthardt, & Weiss, 2005). Considering this, an implicit trauma-relevant cue (i.e., not purposefully recalling details of the traumatic event) may serve as a safer means of eliciting bodily arousal, particularly with higher-risk participants. Together, the use of the hyperventilation challenge as a trauma-relevant cue to elicit bodily arousal and subsequent desire to drink will uniquely extend extant literature both generally, as an alternative to script-driven imagery in adult work, and specifically, among emerging adult college students exposed to trauma.

Integrative Summary and Current Study

An established and growing body of work indicates strong and consistent associations between trauma exposure, posttraumatic stress, and problematic alcohol use (e.g., Stewart, 1996). However, to date, most of the work concerning these

relationships has investigated clinical co-occurrence, etiological mechanisms, and developmental pathways through broad examination of the general adult population (Jacobsen et al., 2001; Pietrzak et al., 2011; Simpson et al., 2014). Better understanding the underlying mechanisms driving this relationship across populations, within sensitive developmental periods (e.g., emerging adult), and incorporating more nuanced assessments (e.g., experimental) is key to the design of effective, developmentally-sensitive intervention and treatment efforts (Blumenthal et al., 2008; Masten, Faden, Zucker, & Spear, 2008; Perrin, Smith, & Yule, 2000).

Examining the association between bodily arousal and alcohol use among emerging adult college students may be particularly meaningful for at least three reasons. First, emerging adulthood is a developmental phase of neurological and somatic changes—including changes in bodily arousal (Buchanan, Eccles, & Becker, 1992)—that initiate during puberty and can continue into emerging adulthood (Crone & Dahl, 2012). Second, emerging adulthood represents a unique period of simultaneous increases in personal freedoms (e.g., living away from home, control over schedule), interpersonal instability (e.g., with friendships, romantic partners; Shulman & Connolly, 2013), continued development of habits and coping strategies (Zaleski, Levey-Thors, & Schiaffino, 1998), and a desire for interpersonal and intrapersonal exploration, including willingness to use substances and engage is risky behavior (Arnett, 2000; 2014; Tanner, 2006). Lastly, the use of alcohol and binge drinking are not only normalized on college campuses (Chen & Kandel, 1995; Lee et al., 2010), but also at their lifetime peak for emerging adult students (Griffin, 2010), including being notably higher than their similar-aged, non-college student peers (SAMHSA, 2014b; 2014c; 2014d).

Collectively, these factors may put trauma-exposed emerging adult college students at particular risk for using (or wanting to use) alcohol when experiencing increased bodily arousal.

Correlational and prospective work among emerging adult college students supports a link between posttraumatic stress—particularly, hyperarousal symptoms—and alcohol use behaviors (e.g., Read et al., 2012). Drawing from theoretical and experimental general adult literature, evidence suggests that exposure to bodily arousal (e.g., elevated heart rate) following a traumatic event not only plays an important role in the development of posttraumatic stress (e.g., Pitman et al., 2012; Pole, 2007), but can also elicit cravings and desire to consume alcohol (e.g., Coffey et. al, 2010; Sinha et al., 2009). However, existing work has several methodological shortcomings that need to be addressed: a) primary focus on clinical populations (e.g., Coffey et al., 2002) and/or with relatively small samples (e.g., Saladin et al., 2003); b) no work utilizing trauma-relevant cues designed to reduce affective, attentional, or recall biases (e.g., voluntary hyperventilation); c) no work specifically examining the influence of bodily arousal on desire to drink among trauma exposed emerging adults, and d) no laboratory-based work to establish temporal precedence and infer cause-and-effect relationships among trauma-cues (such as bodily arousal) and alcohol use among emerging adults. The current study was designed to address these concerns and uniquely extend the extant literature by testing whether the trauma-relevant cue of bodily arousal elicited via voluntary hyperventilation increased desire to drink above and beyond a normal breathing control task among trauma-exposed emerging adult college students.

More specifically, participants completed both a voluntary hyperventilation

challenge and a normal breathing control task in a counterbalanced order (i.e., 40 participants presented with the voluntary hyperventilation challenge first; 40 participants presented with normal breathing control task first; order determined via block randomization; see Figure 1 for procedural overview). This within-subjects design was chosen for three major reasons. First, within-subjects assessments increase internal validity by reducing variability due to inherent differences *between* participants (e.g., participant disposition; MacKenzie, 2013). Second, within-subjects designs are more externally valid for tasks where both manipulations are naturally possible or likely for any given participant (Charness, Gneezy, & Kuhn, 2012); more specifically, in the current study, it is highly likely participants will encounter situations in which they are not experiencing bodily arousal (e.g., during period of rest, sitting), as well as situations in which they are experiencing bodily arousal (e.g., exercise, in response to fear) during their day-to-day life. Lastly, while within-subjects designs can be confounded with carry-over effects between tasks, this limitation can be largely controlled for through counterbalancing the order of the tasks across all participants (Greenwald, 1976). Considering these methodological strengths, this design was used to test the following hypotheses.

Preliminary Hypotheses (Manipulation Checks)

In assessing the effectiveness of the tasks, it was hypothesized that there would be a significant increase in self-reported anxiety/distress and physiological arousal symptoms during the voluntary hyperventilation task, as compared to the normal breathing control task (**H1**). Second, in assessing potential carry-over effects, it was

hypothesized that there would be no significant difference between participants who completed the voluntary hyperventilation task first (n = 40) and the participants who completed the normal breathing task first (n = 40) in their between-tasks desire to drink difference scores (i.e., change in desire to drink after the voluntary hyperventilation challenge, as compared to changes in desire to drink after the normal breathing control task) (**H2**)..

Primary Hypotheses

Third, it was hypothesized that there would be a significant increase in desire to drink during the voluntary hyperventilation task above any identified change in desire to drink in the normal breathing control task (H3). Finally, it was hypothesized that this result would be robust to the inclusion of several theoretically- and empirically-relevant demographic (e.g., biological sex) and psychological variables (e.g., negative affect, anxiety sensitivity) in the model (H4).

Secondary Hypotheses

Although no epidemiology or experimental work has specifically evaluated differential associations between trauma-related arousal and alcohol use willingness, there is a sizeable literature evidencing differences in PTSD symptom presentation (e.g., symptom endorsement, severity), as well as alcohol use outcome, depending on the nature of the traumatic event. For example, research focused on PTSD severity within the general population has suggested that interpersonal trauma types (e.g., sexual assault, robbery, combat) are most strongly associated with posttraumatic stress

symptom severity and the development of PTSD, as compared to non-interpersonal trauma types (e.g., natural disasters, death of a loved one; Amir, Kaplan, & Kotler, 1996; Chung & Breslau, 2008; Smith et al., 2016). These difference in PTSD symptom presentation may have a substantive impact on the development of maladaptive coping mechanisms, such as anxiolytic use of alcohol. Indeed, the strength of associations between PTSD and problematic alcohol use does appear to differ in research targeting specific interpersonal (e.g., intimate partner violence; Sullivan & Holt, 2008). and non-interpersonal subpopulations (e.g., disease/accident-related traumatic injury; Kearns et al., in press). As such, exploratory analysis will be conducted to examine differences in desire to drink during the voluntary hyperventilation task, above any identified in the normal breathing control task, based on trauma type (interpersonal vs. non-interpersonal). More specifically, it was hypothesized that individuals who reported an interpersonal trauma type as their most traumatic event would evidence a significantly greater increase in desire to drink during the voluntary hyperventilation task above any change in desire to drink identified in the normal breathing control task in comparison to individuals who reported a non-interpersonal trauma type as their index event (H5). Finally, it is hypothesized that this result will be robust to the inclusion of theoretically- and empirically-relevant demographic (e.g., biological sex) and psychological variables (e.g., negative affect, anxiety sensitivity) in the model (H6).

Method

Participants

The final sample was comprised of 80 emerging adult college students (M =

20.34, SD = 1.91; 63.8% female) who experienced at least one DSM-5 Criterion A traumatic event (APA, 2013) and reported a positive history of past-month alcohol use. Participants were recruited between April 2017 and November 2017 from the University of North Texas' SONA System, a computerized system for managing university research participation. Of the total 85 college students recruited into the study, three participants were excluded due to age (i.e., older than 25), and two were excluded due to no past-month alcohol use. Notably, no participants met any of the other listed exclusion criteria: a) provisional diagnosis of lifetime panic disorder (PD) or current severe alcohol use disorder; b) positive history of cardiac (e.g., hypertension) or respiratory (e.g., asthma) problems related to physiological arousal; c) current respiratory infection (e.g. pneumonia); d) current/suspected pregnancy (female participants only); or e) limited mental capacity or inability to provide informed, written consent to participate in the study. Please see Table 1 for full descriptives of the final sample.

Rationale for Inclusion and Exclusion Criteria

A number of theoretically and empirically relevant criteria were considered for participation in the current study, aimed at best balancing a) internal validity (e.g., ability to examine both between- and within-subjects differences within a standardized protocol); b) methodological rigor (e.g., ensuring DSM-criteria trauma exposure); c) the external validity (e.g., generalizability); and d) ethical (e.g., safety of participants) and pragmatic (e.g., temporal limitations to thesis data collection) constraints of the current study.

In terms of inclusion criteria, eligible participants must have reported at least one lifetime DSM-5 traumatic event, past month alcohol consumption, and chronological age 18-25 years. First, given the primary aim of assessing the influence of bodily arousal on desire to drink alcohol among trauma-exposed emerging adult college students, it was critical to internal validity that the current study accurately and reliably assess traumatic event exposure using the most up-to-date criteria in the Diagnostic and Statistical Manual (DSM; APA, 2013). For this purpose, participants completed the Life Events Checklist for DSM-5 (LEC-5; Weathers et al., 2013), which was developed concurrently with the "gold standard" Clinician-Administered PTSD Scale (CAPS). The current study took a conservative approach to defining trauma exposure, allowing only participants who have personally experienced an event to participate (i.e., the event "happened to me")—a technique commonplace in adult trauma research (e.g., Paulus, Vujanovic, & Wardle, 2016; Thornley, Vorstenbosch, & Frewen, 2016). Further, given that much of the limited trauma research within emerging adulthood has utilized less specified trauma history measures (e.g., Frye & Liem, 2011; Woo, & Brown, 2013), assessment of trauma exposure using an established measure also served as an important extension to the literature.

In terms of alcohol use, only students who endorsed recent consumption (i.e., at least one standard drink in the past month; Cooper, 1994; Cooper et al., 1995) were included in the study. Similar to assessing traumatic event exposure, ensuring that all participants have recently drank is integral to internal validity, as students without a recent history of alcohol consumption (or no lifetime consumption history) may not evidence change in desire to drink following the elicitation of bodily arousal. The

minimum criteria for “recent” alcohol consumption is notably less strict than some other alcohol-focused emerging adult work (e.g., four standard alcoholic beverages in the past month, Gonzalez, Reynolds, & Skewes, 2011); however, this threshold was purposefully modest to allow for a wider spectrum of drinkers within the current study and greater external validity (i.e., generalizability) of the potential findings.

For age inclusion criteria, restricting participants to ages 18 to 25 was critical to advancing the literature on emerging adult college students for two reasons. First, in the extensive literature that has highlighted emerging adulthood as distinct (e.g., developmentally) from general adulthood, the proposed and generally accepted age range has been between the ages of 18 and 25 (e.g., see Arnett, 2000). Second, although the majority of undergraduate college students at four-year universities fall within this age range, there are a growing number of “nontraditional” college students, often defined as students 25 years of age or older (Hirschorn, 1988; Spitzer, 2000). Empirical work demonstrates distinct differences in type of stressors (e.g., Dill & Henley, 1998), metacognition and motivation (e.g., Justice & Dornan, 2001), and coping strategies (e.g., Morris, Brooks, & May, 2003) between traditional and nontraditional students. Given these differences, it was critical for internal validity that that the current study capture, as best as possible, college students that are still within the emerging adult developmental phase.

In terms of psychological exclusion criteria, participants were not allowed to participate if they met criteria for a provisional diagnosis of lifetime PD or current severe AUD. These provisional diagnoses were determined by structured clinical interviews (i.e., relevant modules of SCID-5-RV; First, Williams, Karg, & Spitzer, 2014), according

to the DSM-5 (APA, 2013). Exclusion based on these particular psychological disorders was determined based on their empirical and theoretical relevance to the experimental task and potential physiological response (i.e., voluntary hyperventilation eliciting bodily arousal), as well as the primary aims of the task (i.e., evoked distress and desire to drink). Emerging adult college students that meet general inclusion criteria (i.e., trauma exposed and recent alcohol users), but also evidence one or more of these conditions may have been at greater risk to suffer adverse reactions (e.g., severe distress, panic attack) to the procedures involved in the study.

It is important to note that these exclusionary criteria were conservative given that these procedures have been used extensively in clinical populations without adverse effect, including studies of patients with PD (e.g., Meuret, Ritz, Wilhelm, & Roth, 2005). Similar work also has been conducted with alcohol use. For example, a study by Pratt and Davidson (2005) found that alcohol assessment did not put alcohol-dependent participants at risk for increased alcohol use at the conclusion of the study. Although this conservative approach to screening participants may reduce the generalizability of these findings to higher-risk emerging adult college students, these exclusion criteria may serve to improve the internal validity of the study, since the presence of these psychological conditions may confound the results; more specifically, inclusion of participants meeting diagnostic criteria for lifetime PD or current severe AUD may make it difficult to determine if any subsequent findings are due to the influence of bodily arousal or to specific clinical conditions (Zvolensky, Lejuez, Stuart, & Curtin, 2001).

Considering the aim of balancing methodological rigor, internal validity, and

external validity, it is important to note that the current study did not exclude for other psychological conditions (e.g., depression, personality disorders, PTSD), subthreshold PD, or mild or moderate AUD symptomatology for three reasons. First, there is no empirical basis for individuals with other conditions to be at greater than minimal risk by participating in the study (e.g., Larsen & Berenbaum, 2014). Notably, for PTSD, voluntary hyperventilation has been used extensively in clinical samples without adverse reaction (e.g., Berenz, Vujanovic, Coffey, & Zvolensky, 2012). Further, empirical work demonstrates that completing questions regarding negative or traumatic events puts participants at no more than minimal risk and may actually be helpful for the participants in terms of subsequent stress responding (Chu & DePrince, 2013; Larsen & Berenbaum, 2014). Importantly, not excluding participants for a provisional diagnosis of PTSD will allow for a wider spectrum of symptom severity within the current study and greater external validity (i.e., generalizability) of the potential findings. Second, screening for history of all potential psychological disorders would place undue burden on participants, which could potentially cause a threat to internal validity (e.g., McCambridge et al., 2011). Third, exclusion of participant with any current psychological conditions or subthreshold symptomatology would innately produce an overly "healthy" sample of emerging adult college student that may limit generalizability of the findings.

Finally, in terms of medical exclusion criteria, participants were not allowed to participate if they reported: a) a positive history of cardiac (e.g., hypertension) or respiratory (e.g., asthma) problems related to physiological arousal; b) current respiratory infection (e.g. pneumonia); or c) current pregnancy or possible pregnancy. These medical exclusion criteria are standard in other studies that have used voluntary

hyperventilation as a means of evoking bodily arousal (e.g., Carter, Suchday, & Gore, 2001; MacDonald, Stewart, Hutson, Rhyno, & Loughlin, 2001) and are meant to protect participants from greater than minimal risk for an adverse reaction to the challenge task.

Measures

Trauma Exposure

The Life Events Checklist for DSM-5 (LEC-5; Weathers et al., 2013) was administered to establish the presence of a DSM-5 Criteria A traumatic event (APA, 2013). The original LEC was developed concurrently with the Clinician-Administered PTSD Scale (CAPS) and demonstrates adequate to good psychometric properties in comparison to other established measures of trauma history (Gray, Litz, Hsu, & Lombardo, 2004). The LEC-5 consists of 16 specified potentially traumatic events, as well as one unspecified traumatic event. Sample items include, “Life-threatening illness or injury” and “Transportation accident (for example, car accident, boat accident, train wreck, plane crash).” Only participants who reported at least one of the 16 specified traumatic events and indicate that the event “happened to them” were be included in the current study. This conservative approach to defining traumatic event exposure has been used in extensively in other trauma research (e.g., Paulus et al., 2016; Thornley et al., 2016). Participants were also asked to choose the most “impacting/traumatic” event from their responses in the LEC-5, prompted by the question, “Which event have you identified as your worst event, which currently bothers you most?” Further, participants were asked to briefly describe that most traumatic event in an open response format. Importantly, participants were included in the study if they indexed a non-specified event

as their “most traumatic” event, as long as they also reported experiencing at least one of the 16 specified traumatic events.

For the exploratory analyses, participants were divided into two groups, based on whether they identified an interpersonal trauma type—defined as trauma that directly inflicted on the participant by another person, such as domestic violence or sexual assault (Mauritz, Goossens, Draijer, & van Achterberg, 2013)—or a non-interpersonal trauma type as their most “impacting/traumatic” event. More specifically, consistent with previous literature (e.g., Luz et al., 2011) participants that endorsed “Physical assault,” “Assault with a weapon,” “Sexual assault,” “Other unwanted or uncomfortable sexual experience,” “Combat or exposure to a war-zone,” or “Captivity” on the LEC-5 as their most traumatic event were provisionally categorized in the interpersonal trauma group; all other specific events (e.g., “Natural disaster,” “Transportation accident”) were provisionally categorized in the non-interpersonal group; participants endorsing an unspecified traumatic event (i.e., “Other very stressful event or experience”) were not assigned to a group and were considered missing data for the exploratory analyses. To ensure accuracy of categorization, all provisional grouping were confirmed and adjusted, accordingly, via qualitative examination of participants’ brief description of their most traumatic event. As seen in Table 1, this resulted in 20 participants in the interpersonal trauma group, 45 participants in the non-interpersonal trauma group, and 15 participants that were excluded from the exploratory analyses. Importantly, these groupings were based on participants’ “most traumatic” event; as such, participants in the non-interpersonal group may have also reported experiencing an interpersonal traumatic event (and visa versa).

History of Alcohol Consumption

An alcohol timeline follow-back procedure (TLFB; Sobell & Sobell, 1992; 2000) was used to assess the recent alcohol use eligibly criterion (i.e., at least one drinking occasion in the past month). Participants were asked to identify specific days they drank alcohol and recall the number of drinks consumed on each of those days in standard alcohol beverages (5 oz. of wine, 12 oz. beer, 1.5 oz. spirits; National Institute on Alcohol and Alcoholism, 2000). For the current study, number of drinking days in the past 30 days were summed. Any participant endorsing zero drinking days in the past 30 days was excluded from the study. The TLFB has been found to have high reliability (Sobell, Brown, Leo, & Sobell, 1996) and has been used extensively with college students (Campos-Melady & Smith, 2012; Grant, Brown, & Moreno, 2013; Kuentzel, Henderson, & Melville, 2008).

Panic Disorder

The Panic Disorder (PD) section in Module F (Anxiety Disorders) of the Structured Clinical Interview for DSM-5 Disorders-Research Version (SCID-5-RV; First, Williams, Karg, & Spitzer, 2014) was administered to establish the presence of lifetime panic disorder. Consistent with DSM-5 criteria for PD (APA, 2013), the SCID-5-RV, participants must meet each of four criteria (i.e., Criteria A through D) to receive a provisional diagnosis of PD. To date, no psychometric data have been published on the SCID-5, although previous iterations of the SCID have demonstrated high inter-rated reliability for PD (e.g., SCID-I; $\kappa = .67$; Lobbestael, Leurgans, & Arntz, 2011).

Alcohol Use Disorder

The Alcohol Use Disorder (AUD) section in Module E (Substance Use Disorders) of the Structured Clinical Interview for DSM-5 Disorders-Research Version (SCID-5-RV; First, Williams, Karg, & Spitzer, 2014) was administered to establish the presence of severe AUD. Consistent with DSM-5 criteria for an AUD (APA, 2013), participants must endorse a problematic patterns of alcohol use leading to clinically significant impairment or distress in the 12 month year, which much manifest in at least two symptoms. According to the DSM-5 (APA, 2013), endorsement of 2-3 symptoms is considered mild AUD, 4-5 symptoms moderate AUD, and 6 or more symptoms severe AUD. To date, no psychometric data have been published on the SCID-5, although previous iterations of the SCID have demonstrated high inter-rated reliability for AUD (e.g., SCID-I; $\kappa = .65$; Lobbestael, Leurgans, & Arntz, 2011.

Medical and Treatment Exclusion Criteria

Lifetime and current history of relevant medical conditions was assessed via a structured medical health interview, similar to questionnaires used in past voluntary hyperventilation work with emerging adult college students (e.g., Carter et al., 2001; MacDonald et al., 2001). Participants were asked about official (i.e., via a medical professional) and/or expected diagnosis of medical conditions. For the current study, participants were excluded if they endorsed any of the following: a) history of cardiac problems related to physiological arousal (e.g., hypertension); b) history of respiratory problems related to physiological arousal (e.g., asthma); c) current respiratory infection

(e.g., pneumonia); d) current pregnancy or possible pregnancy (female participants only).

Negative Affect

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) is a 20-item measure used to assess current positive and negative affect. Participants indicate the extent to which they feel certain emotions "right now, that is, at the present moment." For the current study, only negative affect was examined. Responses are scored on a five-point, Likert-type scale that ranges from 1 ("Very Slight or Not at all") to 5 ("Extremely") and summed to calculate a total score. Higher scores representing higher levels of negative affect. Sample items from the negative affect subscale include, "Distressed," "Hostile," and "Afraid." The PANAS has well-established psychometric properties, including internally consistent, convergent and discriminant validity (Crawford & Henry, 2004; Watson, Clark, & Tellegen, 1988). The PANAS has been used extensively with emerging adult college students (e.g., Demir, 2010; Sirois, 2015). Internal consistency in the current sample was $\alpha = .863$.

Anxiety Sensitivity

The Anxiety Sensitivity Index–3rd Edition (ASI-3; Taylor et al., 2007) is an 18-item measure used to assess participants' anxiety sensitivity. Responses are scored on a five-point, Likert-type scale, with scores ranging from 0 ("Very little") to 4 ("Very much"). Sample items include, "It scares me when I am unable to keep my mind on a task" and "When I begin to sweat in a social situation, I fear people will think negatively of me." Summed scores range from 0 to 72, with higher scores indicated greater anxiety

sensitivity. The ASI-3 demonstrates factorial validity, as well as good psychometric properties, above and beyond the original ASI, including higher reliability and construct validity (Kemper, Lutz, Bähr, Rddel, & Hock, 2011; Taylor et al., 2007; Wheaton, Deacon, McGrath, Berman, & Abramowitz, 2012). The ASI-3 has been used with samples of emerging adult college students (e.g., Shaver, Veilleux, & Ham, 2013). Internal consistency in the current sample was α = .887.

Depression

The Patient Health Questionnaire (PHQ-9; Kroenke & Spitzer, 2002; Löwe, Kroenke, Herzog, & Gräfe, 2004) is a nine-item measure used to assess depression over the past two weeks. Responses are scored on a four-point, Likert-type scale, with scores ranging from 0 (“Not at all”) to 3 (“Nearly every day”). Sample items include, “Little interest or pleasure in doing things,” “Feeling tired or having little energy,” and “Trouble concentrating on things, such as reading the newspaper or watching television.” Summed scores on the PHQ range from 0 to 27, and higher scores indicated greater severity of depression. The PHQ-9 demonstrates good psychometric properties, including reliability, construct, convergent, and discriminant validity (Kroenke & Spitzer, 2002; Martin, Rief, Klaiberg, & Braehler, 2006), as well as sensitivity to changes in depression over time (Löwe et al., 2004). The PHQ-9 has been used extensively with emerging adult college students (e.g., Gomez, Miranda, & Polanco, 2011; Hefner & Eisenberg, 2009). Internal consistency in the current sample was α = .871.

Voluntary Hyperventilation

The voluntary hyperventilation challenge (Hornsveld, Garssen, & van Spiegel, 1995) was used as the trauma-relevant cue to elicit bodily arousal (e.g., elevated heart rate). Following a three-minute baseline breathing period, the challenge involved three minutes of voluntary hyperventilation. Before the task began, participants were provided with the following pre-instructions visually:

> Now we will begin the breathing exercise. In this exercise, you will be asked to breathe in and breathe out very deeply. The instructions will tell you when you should inhale and when you should exhale. Simply breathe in when asked to "inhale," and breathe out when asked to "exhale" – making each breath in as deep as possible and breath out as forceful as possible. It is important that you follow these instructions as best as you can, and continue the exercise until you are asked to stop and rest.

Following these instructions participants were instructed to take full capacity breaths every two seconds (i.e., 30 respiratory cycles per minute) – a breathing rate standard for this challenge with evidenced elicitation of bodily arousal (e.g., elevated heart rate; Brown, Smits, Powers, & Telch, 2003; Sullivan et al., 2004) – facilitated by the Paced Breathing application. The Paced Breathing application allows for specified inhalation/exhalation times (within one millisecond), provides a visual timer for the total duration of the task, and, importantly, provides visual (i.e., a rising/falling bar with the words "Inhale" and "Exhale") and auditory (i.e., different tones for inhalation and exhalation periods) feedback to facilitation standardization and uniformity of breathing rate between participants.

Following the task, participants had a seven-minute recovery period. Although the voluntary hyperventilation challenge lacks the methodological rigor of more controlled paradigms (e.g., CO2-enriched air challenge; Zvolensky & Eifert, 2001), work

utilizing the challenge consistently supports its effectiveness in eliciting bodily arousal (e.g., Feldner, Vujanovic, Gibson, & Zvolensky, 2008), negative affect/distress (e.g., Hawks, Blumenthal, Feldner, Leen-Feldner, & Jones, 2011) and trauma-relevant memories (e.g., re-experiencing symptoms; Nixon & Bryant, 2005) in other trauma-exposed samples.

Normal Breathing Control

In addition to the voluntary hyperventilation challenge, participants completed a normal breathing control task. This task mimicked all aspects of the voluntary hyperventilation challenge (i.e., assessments, baseline period, task duration time, and recovery) with the exception of slightly modified instruction for breathing rate. More specifically, participants were provided with a three-minute baseline breathing period and were presented with the same pre-instructions for the task (see above). Following those instructions, for the normal breathing control, participants were provided the following instructions:

> Now we will begin the breathing exercise. In this exercise, you will be asked to breathe in and breathe out by inhaling and exhaling as you normally would. The instructions will tell you when you should inhale and when you should exhale. Simply breathe in when asked to "inhale," and breathe out when asked to "exhale" – remember to breathe in as deeply as you normally would and breathe out as forcefully as you normally would. It is important that you follow these instructions as best as you can, and continue the exercise until you are asked to stop and rest.

Following these instructions participants were instructed to take "normal" capacity breaths every four seconds (i.e., 15 respiratory cycles per minute) facilitated by the Paced Breathing application. Following the task, participants had a seven-minute recovery period

Filler Task Questionnaire

In an effort to reduce carry over effects between tasks and provide attentional recovery time, participants completed a questionnaire comprised of affectively-neutral questions between the voluntary hyperventilation challenge and normal breathing control task. The "filler" questionnaire involved up to 18 open-ended questions specifically chosen to not evoke memories of the trauma exposure, posttraumatic stress symptoms, or alcohol consumption. Sample items include, "What is your favorite kind of pie/cake? Describe taking a bite using three adjectives," "If you could be any color in a Crayola box, what color would you be? Why?," and "Describe the color yellow to somebody who is blind." Participants answered questions for five minutes. If the participant completed all 18 items before the five minutes has elapsed, they were instructed to wait patiently until additional instructions were provided.

Baseline Anxiety/Distress and Reactivity to Tasks

Throughout the testing session, participants were asked to complete the Subjective Units of Distress Scale (SUDS; Back et al., 2014.; McCabe, 2015; Wolpe, 1958) to assess current anxiety/distress. Specifically, participants were asked to rate their current level of anxiety or distress on a scale of 0 ("no distress; totally relaxed") to 100 ("Highest anxiety/distress that you have ever felt"). The SUDS is an established method of assessing self-reported, real-time distress (e.g., Bremner et al., 1999; Lund, Reider, Whiting, & Prichard, 2010). Further, participants were asked to complete a 16-items subset of psychological and physiological arousal items from from the Panic Attack Questionnaire (PAQ; Norton, Harrison, Hauch, & Rhodes, 1985) to assess for

current physiological arousal. Specifically, participants were asked to rate each of the symptoms on a five-point, Likert-type scale, ranging from 0 (“None at all”) to 4 (“Very Severe”). Sample items include “chest pain or discomfort,” “heart pounding,” and “tingling in hands or feet.” Both the SUDS and PAQ were given at seven timepoints: during baseline assessment, before their first breathing task baseline period (baseline1), immediately after their first breathing task (post1), after their first breathing task recovery period (recovery1), before their second breathing task baseline period (baseline2), immediately after their second breathing task (post2), and after their second breathing task recovery period (recovery2).

Desire for Alcohol

The abbreviated form of the Desires for Alcohol Questionnaire (DAQ; Clark et al., 1996; Love, James, & Willner, 1998) is a 14-item measure that was used to assess participants’ current desire to consume alcohol. Participants are asked which agreement level best describes how they feel “right now.” Responses are scored on a five-point, Likert-type scale, with scores ranging from 1 (“Strongly Disagree”) to 5 (“Strongly Agree”) with a neutral midpoint 3 (“Neither Agree or Disagree”). Although there are no established subscales, items generally assess urges for alcohol, anticipation of positive and negative reinforcement from drinking, and expectations of control over drinking, which hold together in a 4-factor (e.g., Love et al., 1998) or 3-factor structure (e.g., Kramer et al., 2010). Sample items include, “I want a drink so much I can almost taste it,” “I would feel as if all the bad things in my life had disappeared if I drank now,” and “Drinking would be satisfying now.” Summed scores range from 14 to 70, with higher

scores indicating greater desire to consume alcohol. In addition to the SUDS and PAQ (above), the DAQ was administered at seven timepoints: during baseline assessment, before their first breathing task baseline period (baseline1), immediately after their first breathing task (post1), after their first breathing task recovery period (recovery1), before their second breathing task baseline period (baseline2), immediately after their second breathing task (post2), and after their second breathing task recovery period (recovery2). Each administration of the DAQ presented the 14 questions in a randomized order to reduce sequence effects. The DAQ has demonstrated good internal consistency and concurrent validity, with favorable reliability over other measures of alcohol craving (Love et al., 1998; Kramer et al., 2010), and positively correlates with problematic drinking (Pasche, Garner, Baldwin, & Sinclair, 2013). The DAQ has been used in both clinical (e.g., Tapert, Brown, Baratta, & Brown, 2004) and non-clinical (e.g., Dickter, Forestell, Hammett, & Young, 2014) populations of emerging adults.

Procedure

All procedures were approved by the University of North Texas Institutional Review Board. Participants were recruited from the University of North Texas' SONA System, which provided a detailed overview of the study, as well as a detailed list of inclusion and exclusion criteria (e.g., ages 18-25, past-month drinking). Compensation was provided in the form of course credit consistent with the standard procedures of the department. Upon arrival, students were required to read a statement of informed consent and were provided a mental health resources form (i.e. a copy of local, university, and national mental health resources). Consent materials included an

overview of the types of questions that were asked (e.g., medical history, trauma history), a detailed description of the voluntary hyperventilation challenge, including the potential effects of the task (e.g., elevated heart rate, sweating), guidelines for confidentiality, and the voluntary nature of participation. Following the informed consent, the medical history questionnaire and baseline questionnaires (detailed above) were completed on a private computer through Qualtrics - a highly secure and encrypted data collection tool (see http://www.qualtrics.com/security-statement), consistent with HIPPA and FERPA guidelines. After the baseline questionnaires, the PD and AUD sections of the SCID-5-RV were administered privately to participants to further assess for exclusion criteria. Lastly, participants completed an alcohol timeline follow-back to assess for alcohol consumption over the past 30 days. Participants meeting all inclusionary and exclusionary criteria were randomly assigned (via block randomization) to the order in which they completed the voluntary hyperventilation challenge and the normal breathing control task.

Prior to instructions for the first breathing task (baseline1), participants completed the Desires for Alcohol Questionnaire (DAQ), Subjective Units of Distress Scale (SUDS), and physiological arousal questions (via modified PAQ). After a three-minute baseline period, participants began their breathing task, as described in the Laboratory-based challenge indices section. Immediately after the first breathing task (post1), participants completed the DAQ, PAQ, and SUDS again. Last, at the end of that seven-minute recovery period (recovery1), participants completed their final DAQ, PAQ, and SUDS. Between tasks, participants completed the five-minute filler questionnaire (i.e. non-essential questions; please see appendix), designed to provide additional recovery

time between tasks, as well as reduce potential carry-over effects from the previous task. Following the filler questionnaire, participants repeated the same procedure (see above) for the second breathing task. More specifically, participants: 1) completed the DAQ, PAQ, and SUDS (baseline2), 2) had a three-minute baseline period, 3) completed second breathing task, 4) completed the DAQ, PAQ, and SUDS (post2), 5) had a seven-minute recovery period, and 6) completed the final DAQ, PAQ, and SUDS (recovery2). Importantly, both the researcher and participant were blinded to the order in which the voluntary hyperventilation challenge and the normal breathing control task was administered until after the baseline questionnaires and structured clinical interviews had been completed in order to minimize expectancy effects.

After completion of the study, participants completed a funneled debriefing, which included several questions asking (1) if participants felt they were expected to react or answer in any particular way and (2) whether or not they experienced any remembering of their traumatic event during the task, including which task that memory was evoked during, the indexed trauma associated with the memory, and the vividness of the memory. Additional information provided within the debriefing focused on potential risk following traumatic event exposure (i.e. development of posttraumatic stress symptoms and/or maladaptive coping strategies, such as substance use), as well as the primary aim of the study to assess the influence of bodily arousal on subsequent desire to drink. This aim was briefly described in terms of forwarding the literature on emerging adult college students, which may serve to inform prevention and intervention efforts in the future. Participants were given an opportunity to ask questions about the study (i.e. reasons for the interviews) and encouraged to provide feedback on the procedures.

After thanking the participant for their time and ensuring they retained their mental health resources form, participants were appropriately compensated in SONA Systems.

Data Analytic Plan

Power Analysis

No research has been conducted to assess the influence of bodily arousal via voluntary hyperarousal on subsequent desire to drink among emerging adult college students. However, laboratory-based work within the adult literature using alternative trauma-relevant cues (e.g., script-driven imagery) have evidenced moderate-large effect sizes when eliciting desire to drink (e.g., Coffey et al., 2006). An a priori power analysis conducted in G*Power 3.1.2 conservatively based on a small-medium effect size ($d = .35$) and standard parameters for alpha ($\alpha = .05$) and power (.80), suggesting that a sample size of 67 participants. As such, a sample of 80 trauma-exposed college students was determined for the current study to ensure even distribution of participants across groups and to increase power.

Preliminary Analysis

To assess the efficacy of the voluntary hyperventilation task in eliciting the desired effect (i.e., manipulation check; **H1**), difference scores were calculated for a) anxiety/distress (via SUDS) after the hyperventilation task, as compared to anxiety/distress before the baseline period for the hyperventilation task and b) anxiety/distress (via SUDS) after the normal breathing, as compared to anxiety/distress before the baseline period for the normal breathing task. After these scores were

calculated, a paired-samples t-test was conducted to assess if there was a difference between participants' change in anxiety/distress during the hyperventilation task and participants' change in anxiety/distress during the normal breathing task (i.e., between-tasks difference score). The same process was conducted for the between-tasks physiological arousal (PAQ) difference score.

To address the second hypothesis (i.e., examination of a potential carry-overs effect; **H2**), an independent samples t-test was conducted to assess if there was a difference in desire to drink between-task difference scores (i.e., change in desire to drink after the hyperventilation task, in comparison to change in desire to drink after the normal breathing task) between participants who received the hyperventilation task first (n = 40) and participants who received the normal breathing task first (n = 40).

In addition to the aforementioned manipulation checks, demographic (i.e., biological sex, age, race/ethnicity, class rank) and theoretically-relevant psychologically and behavioral baseline characteristics (i.e., negative affect, depression, anxiety sensitivity, alcohol use frequency) were examined to assess their influence on the primary outcome measure. More specifically, a series of t-tests (for dichotomous categorical variables; e.g., biological sex), univariate analyses of variance (for non-dichotomous categorical variables; e.g., race/ethnicity), and simple linear regression (for continuous and ordinal variables; e.g., anxiety sensitivity) analyses were conducted. All variables that were significantly associated with desire to drink between-tasks difference scores (i.e. $p < .05$ association with desire to drink) were included in the second primary analysis (see below) as covariates.

Primary Analyses

To assess the third hypothesis (**H3**), difference scores were calculated for a) desire to drink after the hyperventilation task compared to desire to drink before the baseline period for the hyperventilation task and b) desire to drink after the normal breathing compared to desire to drink before the baseline period for the normal breathing task. A paired-samples t-test was conducted to assess if there was a difference between participants' change in desire to drink during the voluntary hyperventilation task, as compared to the normal breathing task.

Second, a univariate analysis of covariance (ANCOVA) was conducted to examine if the result of the first primary analysis was robust to the inclusion of theoretically- and empirically-derived covariates (**H4**). More specifically, demographic, psychological, and behavioral (e.g., biological sex, negative affect, depression) variables significant at the $\alpha = .05$ level (see above) were included as covariates in the model as fixed factors.

Secondary Analyses

Exploratory analyses examined differences in participants' change in desire to drink during the voluntary hyperventilation task, as compared to the normal breathing task, between individuals reporting an interpersonal trauma type as their most traumatic event and individuals reporting a non-interpersonal trauma type as their most traumatic event (**H5**). More specifically, an independent-samples t-test was conducted to comparing between-tasks desire to drink difference scores between interpersonal and non-interpersonal trauma groups.

Second, a univariate analysis of covariance (ANCOVA) was conducted to examine if the result of the first secondary analysis was robust to the inclusion of theoretically- and empirically-derived covariates (**H6**). More specifically, demographic, psychological, and behavioral (e.g., biological sex, negative affect, depression) variables significant at the $\alpha = .05$ level (see above) were included as covariates in the model as fixed factors.

Results

Preliminary Analyses

Sample Descriptives

Across all participants, the median alcohol consumption rate was 2-4 times a month, and did not differ as a function of random group assignment [$t(78) = 1.45$, $p = .150$). Regarding PTSD symptoms, total scores on the PTSD Checklist ranged from 0 to 69 ($M = 19.06$, $SD = 16.14$), and did not differ as a function of random group assignment [$t(77) = 0.40$, $p = .693$]. See Table 1 for detailed sample descriptives.

Preliminary Analyses

Prior to all analyses, statistical assumptions were examined (e.g., normality) and were met. To assess the efficacy of the voluntary hyperventilation task in eliciting the desired effect (i.e. manipulation check; H1), between-tasks difference scores for anxiety/distress and physiological arousal were examined. Results showed that there was a significantly greater increase in self-reported anxiety/distress following the voluntary hyperventilation challenge ($M = 18.76$, $SD = 22.11$) than following the normal

breathing control task [M = -2.61, SD = 12.21; t(79) = 7.46, p < .001, d = 1.07]. Similarly, results showed that there was a significantly greater increase in self-reported physiological arousal following the voluntary hyperventilation challenge (M = 8.80, SD = 8.82) than following the normal breathing control task [M = 1.18, SD = 3.77; t(73) = 7.66, p < .001, d = 1.12]. Full descriptives of pre-task, post-task, change, and between-tasks difference scores for anxiety/distress and physiological arousal can be found in Table 2. Mean values for change in self-reported anxiety/distress and physiological arousal during the voluntary hyperventilation challenge and normal breathing control task are also presented in Figure 2.

To assess for potential carry-over effects (ordering effects; H2), differences between participants' change in desire to drink during the hyperventilation task and participants' change in desire to drink during the normal breathing control task were examined between participants who received the hyperventilation task first and participants who received the normal breathing control task first. Results showed no statistically significant difference in between-tasks desire to drink difference scores between the group that received the voluntary hyperventilation challenge first (M = -1.00, SD = 9.17) and the group that received the normal breathing control task first [M = 1.92, SD = 6.79; t(73) = -1.56, p = .122, d = 0.36].

Last, a series of t-tests, ANOVAs, and simple linear regression analyses assessed the potential influences of demographic (i.e. biological sex, age, race/ethnicity, class rank) and theoretically-relevant psychologically and behavioral baseline characteristics (i.e. negative affect, depression, anxiety sensitivity, alcohol use frequency) on change in desire to drink. Results showed that only negative affect was

statistically significantly associated with between-tasks desire to drink difference scores (p = .009). Associations between between-tasks desire to drink difference scores and biological sex (p = .881), age (p = .232), race/ethnicity (p = .498), class rank (p = .520), depression (p = .929), anxiety sensitivity (p = .136), and past year alcohol use frequency (p = .475) were not statistically significant. As such, only negative affect was included as a covariate in the primary (H4) and secondary robustness analyses (H6).

Primary Analyses

Participants' change in desire to drink during the hyperventilation task was compared to participants' change in desire to drink during the normal breathing control task (H3). Results showed no statistically significant differences in change in desire to drink following the voluntary hyperventilation challenge (M = -0.49, SD = 7.02) compared to change in desire to drink after the normal breathing control task [M = -0.93, SD = 4.49); t(74) = 0.47, p = .642]. Given null results in the base model, robustness analyses with significant covariates were not conducted (H4). Full descriptives of pre-task, post-task, change, and between-tasks desire to drink difference scores can be found in Table 2.

Secondary Analyses

The difference between participants' change in desire to drink during the hyperventilation task and participants' change in desire to drink during the normal breathing control task were examined between participants who reported an interpersonal trauma type as their most traumatic event (n = 20) and participants who

reported a non-interpersonal trauma type as their most traumatic event (n = 45; H5); see Table 1 for full descriptives of the interpersonal and non-interpersonal trauma groups. Results showed that individuals who reported an interpersonal trauma as their most traumatic event reported a significantly greater increase in desire to drink following the voluntary hyperventilation challenge (M = 2.68, SD = 7.10) than individuals who reported a non-interpersonal trauma as their most traumatic event (M = -1.86, SD = 7.93) related to the normal breathing control task, [t(59) = 2.14, p = .037, d = .60].

An ANCOVA was conducted to assess the robustness of this significant finding to inclusion of empirically-derived covariates (i.e., negative affect; H6). Results showed that individuals who reported an interpersonal trauma as their most traumatic event still reported a significantly greater increase in desire to drink following the voluntary hyperventilation challenge, [F(1, 57) = 8.60, p = .005, ηP2 = .13], even after statistically controlling for the significant influence of negative affect (p = .009, ηP2 = .12). Mean values for change in self-reported anxiety/distress, physiological arousal, and desire to drink during the voluntary hyperventilation challenge and normal breathing control task for both the interpersonal and non-interpersonal trauma groups are presented in Figure 3.

Discussion

Alcohol consumption on college campuses is a major public health concern in the United States, particularly among emerging adults (Kilpatrick et al., 2007)—a developmental phase that is theoretically- and empirically-distinct from both adolescence and general adulthood (Arnett, 2000; 2014; 2015), including elevated rates

of problematic alcohol use (e.g., heavy episodic drinking) and AUD (Blanco et al., 2008; Johnston et al., 2011). Extant literature identifies trauma exposure and posttraumatic stress as robust risk factors for excessive alcohol use and the development of related problems (Read et al., 2012; Twamley et al., 2004). However, the mechanisms underlying these associations are less well-studied. Research indicates that bodily arousal (e.g., elevated heart rate) is a fundamental feature of trauma exposure that may manifest into conditioned interoceptive cues, which can later trigger posttraumatic responding and related symptomatology, including alcohol use (Bedard-Gilligan & Zoellner, 2008; Falsetti et al., 1995). Past work with adults has supported this assertion, consistently demonstrating that explicit trauma-relevant cues, such as script-driven imagery, can elicit both physiological arousal and desire to drink (Coffey et al., 2010, Sinha et al., 2009). However, paradigms purposefully designed to evoke memories of the traumatic event make it difficult to ascertain whether the subsequent increase in alcohol craving is catalyzed by the explicit re-experiencing of the trauma or the associated bodily arousal. Accordingly, the current study utilized a laboratory-based, within-subjects design to evaluate whether the trauma-relevant cue of bodily arousal independent of any explicit reminder of the traumatic event would elicit an increase in desire to drink alcohol among trauma-exposed, emerging adult college students. Consistent with hypotheses, preliminary analyses indicated that voluntary hyperventilation was efficacious in eliciting both self-reported distress and physiological arousal, as compared to a normal breathing control task. With regard to theoretically-associated variables, there were mixed findings, with results indicating that only negative affect – but, not depression or anxiety sensitivity – was associated with

increases in desire to drink following induced physiological arousal. Contrary to hypotheses, the primary analyses found no statistically significant difference in change in desire to drink between the hyperventilation task and the control task. Although exploratory in nature, secondary analyses indicated that trauma type—whether individuals reported an interpersonal or non-interpersonal trauma type that their most traumatic event—may play a key moderating role, with results showing that individuals reporting an interpersonal trauma as their most traumatic event evidenced a significantly greater increase in desire to drink after the hyperventilation challenge, as compared to the control task, than individuals who reported a non-interpersonal trauma.

Despite laboratory-based work demonstrating that explicit trauma-relevant cues, such as script-driven imagery, can elicit increases in desire to drink alcohol (e.g., Chaplin et al., 2010, Coffey et al., 2010, Sinha et al., 2009), the null primary finding in the current study suggests that an implicit trauma-relevant cue (i.e., bodily arousal), without any explicit reminder of the traumatic event, may not influence change in desire to consume alcohol across trauma-exposed emerging adult college students. One possible explanation is that bodily arousal is not a specific and/or powerful enough trauma-relevant cue to reliably influence subsequent alcohol cravings, despite evoking an increase in self-reported distress. Indeed, contrary to the high prevalence of reported trauma memories following induced physiological arousal in both non-clinical (Nixon & Bryant, 2005) and clinical adult samples (Wald & Taylor, 2008), there was only a small subset of emerging adult college students (n = 15; 18.8%) that reported vivid re-experiencing of their traumatic event during the voluntary hyperventilation challenge in the current study. Notably, those individuals that did report re-experiencing traumatic

memories evidenced a greater increase in desire to drink following voluntary hyperventilation (M = 3.27), relative to change following the control task, compared to those that did not report any re-experiencing of their most traumatic event (M = -0.33); however, this analysis was underpowered to detect any statistically significant effect (See Table 1 for descriptives of the traumatic memory re-experiencing subgroup; see Figure 3 for comparison of desire to drink between-tasks difference scores). Importantly, among individuals who reported remembering their trauma during the experimental task, there was no association between anxiety/distress and desire to drink (r = .03) or physiological arousal and desire to drink (r = .03); this suggests that the increases in alcohol craving within this subgroup may be trauma-related, as opposed to a general response to increases in anxiety/distress or physiological arousal (see Figure 3 for comparison of self-reported distress and physiological arousal between-tasks difference scores). Collectively, these findings suggest that bodily arousal may only serve as an implicit, trauma-relevant interoceptive cue that increases desire to drink for a specific subset of trauma-exposed, emerging adult college students. Future work is needed to understand the demographic, psychological, and trauma-related characteristics of those individuals that are cued by physiological arousal—an important “next step” in conceptualizing the role of bodily arousal as an implicit trauma-relevant cue that may elicit stress responding, including alcohol cravings, within this at-risk subpopulation.

Findings from the exploratory analyses regarding the influence of trauma type also may partially explain the primary null finding. These results indicate that individuals reporting an interpersonal trauma type as their most traumatic event are at increased risk of experiencing desires to drink following voluntary hyperventilation, relative to

those reporting a non-interpersonal trauma type as their most traumatic event. In fact, the current findings indicate that individuals who reported a non-interpersonal trauma as their most traumatic event reported a decrease in desire to drink following the voluntary hyperventilation task, relative to the control task. This dichotomy, polarized around a net zero, appears to have had a "washing out" effect when participants were averaged together, resulting in null findings in the overall sample. Extant literature regarding associations between trauma type, PTSD symptom presentation (i.e., severity, symptom profile; Contractor et al., 2015), and traumatic memory processing/encoding may partially explain why an implicit, trauma-related cue of physiological arousal appeared to increase desire to drink among those reporting an interpersonal trauma as their most traumatic event, specifically. Epidemiological work indicates that individuals who report an interpersonal trauma as their index trauma are at greater risk for increased posttraumatic stress symptom severity and the development of PTSD, relative to those who index a non-interpersonal trauma (Amir, Kaplan, & Kotler, 1996; Chung & Breslau, 2008; Smith et al., 2016). Early theoretical work suggests that these disparities in symptom presentation and risk for PTSD based on trauma type may be indicative of fundamental differences in memory information processing and encoding at the time of the traumatic event (Bryant, 2003; Nixon & Bryant, 2005; Shalev et al., 1998; Young, 1996). For example, although no empirical work has examined differences in memory information processing between trauma types, interpersonal traumatic experiences, such as physical violence, often involve more intense, acute physiological arousal within a specified, momentary timeframe (i.e., during the violence), whereas non-interpersonal traumatic events, such as natural disasters, often involve

prolonged/intermittent or chronic physiological arousal over the course of several hours or days (e.g., hurricane) that may or may not be directly linked to a specific moment in time during the event (D'Andrea et al., 2012; Green et al., 2000; Newman, Riggs, & Roth, 1997) As such, internal (e.g., bodily arousal) and external (e.g., visual memories) stimuli that occur during interpersonal traumatic experiences (e.g., sexual assault, physical violence, robbery) may be more likely to manifest into conditioned cues that can later trigger posttraumatic stress responding and related symptomatology, such as increased alcohol craving. Notably, in the current sample, 15% of individuals reporting an interpersonal index trauma also reported re-experiencing of their trauma during the study.

It is important to note that the current study was not designed to examine traumatic information processing or internal/external stimuli at the time of initial trauma exposure. Further, the sampling approach in the current study did not account for differences in trauma type, resulting in a sample that was not adequately powered to conduct additional analyses within the interpersonal (n = 20) and non-interpersonal index trauma subgroups (n = 45). As such, future research, powered to examine type of trauma exposure, is needed to replicate and meaningfully extend the current findings. Understanding the potential moderating role of trauma type in the association between bodily arousal and subsequent desire to drink among trauma-exposed emerging adult college students will be a key component to identifying specific subgroups within this at-risk population, which will in turn help inform targeted intervention efforts aimed at reducing problematic alcohol use.

Limitations

The primary and exploratory findings of the current study should be considered in the context of several limitations. First, results may be limited by inherent biases in self-report assessments. Indeed, the procedural manipulation checks (i.e., distress, physiological arousal), primary outcome (i.e., desire to drink), and trauma history indexing for exploratory analyses (i.e., most traumatic event) were assessed via self-report measures. Although not uncommon in the literature (e.g., Coffey et al., 2010), future work should consider use of physiological measurement equipment to capture "real-time" physiological responding (e.g., heart rate, skin conductance) – information that could be combined and/or compared with broader self-reports of physiological symptoms that cannot be examined via biofeedback (e.g., chest pain/discomfort, tingling in hands or feet) for a more accurate and holistic assessment of reactivity to the arousal induction procedure. Further, although desire to drink has evidenced empirical (e.g., Casey, Adamson, Shevlin, & McKinney, 2012; MacKillop et al., 2010) and biological (e.g., Park et al., 2007) links to problematic alcohol use and AUD, future work may consider using an ad libitum alcohol consumption procedure for the primary outcome to improve upon the ecological validity of the findings. Last, future work should consider use of structured clinical interviews (e.g., Clinician-Administered PTSD Scale for DSM-5; Weathers et al., 2013), for a more accurate assessment of trauma history, including detailed examination of trauma history patterns that may influence reactivity to implicit trauma-relevant cues, such as interpersonal/non-interpersonal trauma cross-over (e.g., indexing an interpersonal trauma type as their most traumatic, but also

reporting experiencing of other non-interpersonal traumas), number of exposures to trauma(s), and age(s) of trauma exposure.

Second, the findings in the current study may be limited by several methodological and procedural decisions made in the interest of external validity and generalizability. For example, timeslots were available for participants on each day of the week (i.e., Monday through Sunday) at one of three timeslots: noon (12:00pm), afternoon (2:30pm), and early evening (5:00pm). While this procedure may have partially controlled for the potential influences of weekend/weekday context and time of day on reactivity to the voluntary hyperventilation task, future work should consider either (a) selecting timeslot that occur during hours (e.g., evening, night) and days (e.g., Thursday or weekends) when emerging adult college student are more likely to engage in drinking behavior to improve the ecological validity of the findings or (b) experimentally manipulate appointment times to empirically examine if weekday/weekend context and time of day are associated with alcohol craving reactivity. Further, with the aim of improving generalizability of findings, the current study took a notably liberal approach to operationalizing “recent alcohol use” for the inclusion criteria. Although all participants included in the study met this criteria (i.e., at least one standard alcohol beverage in the past one month), several participants qualitatively reported alcohol use patterns that may have impacted their desire to consume alcohol; for example, several participants noted limited exposure to alcohol use (e.g., using one time in their lifetime, which happened to have occurred in the past month), a recent reduction or decision to abstain from alcohol use, and/or alcohol use only within an event-specific context (e.g., religious, with dinner). Although preliminary

analyses showed no statistically significant association between alcohol use frequency and between-tasks desire to drink difference scores, participants with less experience with alcohol still may have more limited “trauma cue-alcohol consumption” experiential pairings leading to potential variations in responding to a trauma-relevant cue than more frequent, social drinkers. Future work should consider using more standard (i.e., stricter) alcohol use inclusion criteria to collect a more homogenous sample of drinkers to potentially improve interval validity. Last, although preliminary analyses showed no statistically significant association between PTSD symptom severity and between-tasks desire to drink difference scores, there did appear to be notable differences in PTSD symptom severity between the interpersonal/non-interpersonal groups and the traumatic memory re-experiencing/no re-experiencing groups (See Table 1). Future, adequately-powered work targeting trauma-specific groups within this population should consider the influence of PTSD symptoms severity, as this variable may play an important role in understanding why individuals in these subgroups appear to evidence greater reactivity to implicit trauma-relevant cues.

Third, although exploratory and tertiary analyses concerning interpersonal/non-interpersonal trauma and traumatic memory re-experiencing/no re-experiencing subgroups indicate the observed increases in desire to drink were related to bodily arousal as a trauma-relevant cue, as opposed to induction of general distress or arousal, the current study approach did not include a non-trauma-exposed subsample for comparative analyses. Future work should consider replicating the current within-subjects design with both trauma-exposed and non-trauma-exposed emerging adult college students to evaluated whether the observed effects on desire to drink are

exclusive to those who have experienced a trauma. Fourth, despite sample diversity being a relative strength of the current study (e.g., race/ethnicity, class rank, trauma experience, PTSD symptom severity), results reflect the experiences of emerging adult college students at one Southwestern university and may not generalize to samples in other areas of the country. Further, in an effort to optimize interval validity, the current study employed a sampling approach that involved recruitment of emerging adult-aged (i.e., 18-25 years old) recent alcohol users who were relatively healthy (i.e. no respiratory/cardiac condition). As such, caution should be taken in term of generalizing these findings to other contextually- and developmentally- distinct populations, such as emerging adult college students that are alcohol-naïve or individuals with 'severe' AUD.

Conclusion

Despite these limitations, the current study meaningfully expands on our understanding of the underlying mechanisms driving the associations between PTSD and subsequent alcohol use behavior. More specifically, the current study suggests that bodily arousal may serve as an implicit, trauma-relevant interoceptive cue that increases desire to drink, but only within a specific subset of trauma-exposed emerging adult college students. This manuscript provides several suggestions for future directions to help in identifying this subgroup (e.g., individuals reporting an interpersonal trauma as their most traumatic event), as well as methodological and procedural suggestions that may optimize internal validity and improve power to detect the effects of implicit, trauma-relevant cues on desire to drink in future work targeting this at-risk population. The replication and extension of this work among emerging adult college

students will be an important next step in understanding the influence of bodily arousal – independent of explicit evoking of trauma memories – on alcohol use behavior, which will be critical to PTSD-alcohol use modeling and, ultimately, help in informing prevention- and treatment-oriented intervention efforts aimed at reducing problematic alcohol use on college campuses.

Table 1

Descriptive Statistics for Total Sample and Descriptives for Trauma Type and Traumatic Memory Subgroups

Variable	Total Sample (*N* = 80)	Trauma Type		Traumatic Memory Reexperience	
		Interpersonal (*n* = 20)	Non-interpersonal (*n* = 45)	Yes (n = 15)	No (n = 63)
Age[a]	20.34 ± 1.91	20.70 ± 2.06	20.26 ± 1.70	19.93 ± 1.86	20.36 ± 1.86
Biological Sex[b]					
Male	28 (35.0%)	4 (20.0%)	14 (31.1%)	4 (26.7%)	22 (34.9%)
Female	51 (63.8%)	16 (80.0%)	31 (68.9%)	11 (73.3%)	40 (63.5%)
Race[c]					
African American	26 (32.5%)	5 (25.0%)	16 (35.6%)	2 (13.3%)	22 (34.9%)
White	23 (28.8%)	9 (45.0%)	12 (26.7%)	5 (33.3%)	18 (28.6%)
Hispanic	15 (18.8%)	2 (10.0%)	7 (15.6%)	3 (20.0%)	12 (19.0%)
Multiracial/Other	16 (20.0%)	4 (20.0%)	10 (22.2%)	5 (33.3%)	11 (17.5%)
Class Rank					
Freshman	21 (26.3%)	4 (20.0%)	11 (24.5%)	5 (33.3%)	16 (25.4%)
Sophomore	19 (23.8%)	4 (20.0%)	12 (26.7%)	4 (26.7%)	15 (23.8%)
Junior	19 (23.8%)	4 (20.0%)	10 (22.2%)	2 (13.3%)	16 (25.4%)
Senior	21 (26.3%)	8 (40.0%)	12 (26.7%)	4 (26.7%)	16 (25.4%)
PTSD Symptom Severity	19.06 ± 16.14	26.15 ± 16.36	16.36 ± 15.16	27.93 ± 17.83	17.02 ± 15.45
Negative Affect[d]	16.41 ± 6.74	19.10 ± 8.40	15.70 ± 5.98	17.64 ± 7.15	15.97 ± 6.64
Depression[d]	8.21 ± 6.16	10.89 ± 6.77	7.13 ± 5.86	10.27 ± 6.50	7.79 ± 6.10
Anxiety Sensitivity[d]	19.01 ± 12.81	20.20 ± 12.87	17.53 ± 12.43	20.00 ± 10.47	18.67 ± 13.24
Alcohol Use (past year)	2 [1, 2]	2 [1, 2]	2 [1, 2]	2 [1, 2]	2 [1, 2]

Note: Data presented as M ± SD, n (%), and Mdn[IQR]. [a]Data not available for three participants (3.8%). [b]One participant (1.3%) endorse "Other" as their biological sex. [c]Due to small sample size, participants identifying as Asian (*n* = 3; 3.8%), Middle Eastern/Arabic (*n* = 2; 2.5%), "Other" (*n* = 1; 1.3%), and Multiracial (*n* = 10; 12.5%) were combined in the Multiracial/Other category for analysis. [d]Data not available for one participant (1.3%).

Table 2

Pre-, Post-, Change, and Between-Tasks Difference Scores Means for Tasks on Primary Manipulation and Outcome Measures

	Voluntary Hyperventilation			Normal Breathing Task			Between-Tasks Difference		
Variable	Pre	Post	Change	Pre	Post	Change	Score	*t*	*d*
Anxiety/Distress	19.63	38.39	18.76	19.76	17.15	-2.61	21.38 ± 25.65	7.46**	1.20
Physiological Arousal[a]	2.88	11.34	8.80	3.87	5.36	1.18	7.62 ± 8.56	7.66**	1.12
Desire to Drink[b]	28.98	28.46	-0.49	28.05	27.54	-0.93	0.44 ± 8.16	0.47	0.07

Note: Data presented as *M* for pre-, post-, and change scores; data presented as *M* ± *SD* for between-tasks difference scores. Estimated effect size thresholds for Cohen's *d*: 0.2 (small), 0.5 (medium), 0.8 (large). [a]Data not available for six participants. [b]Data not available for five participants. **p < .001. *p < .05.

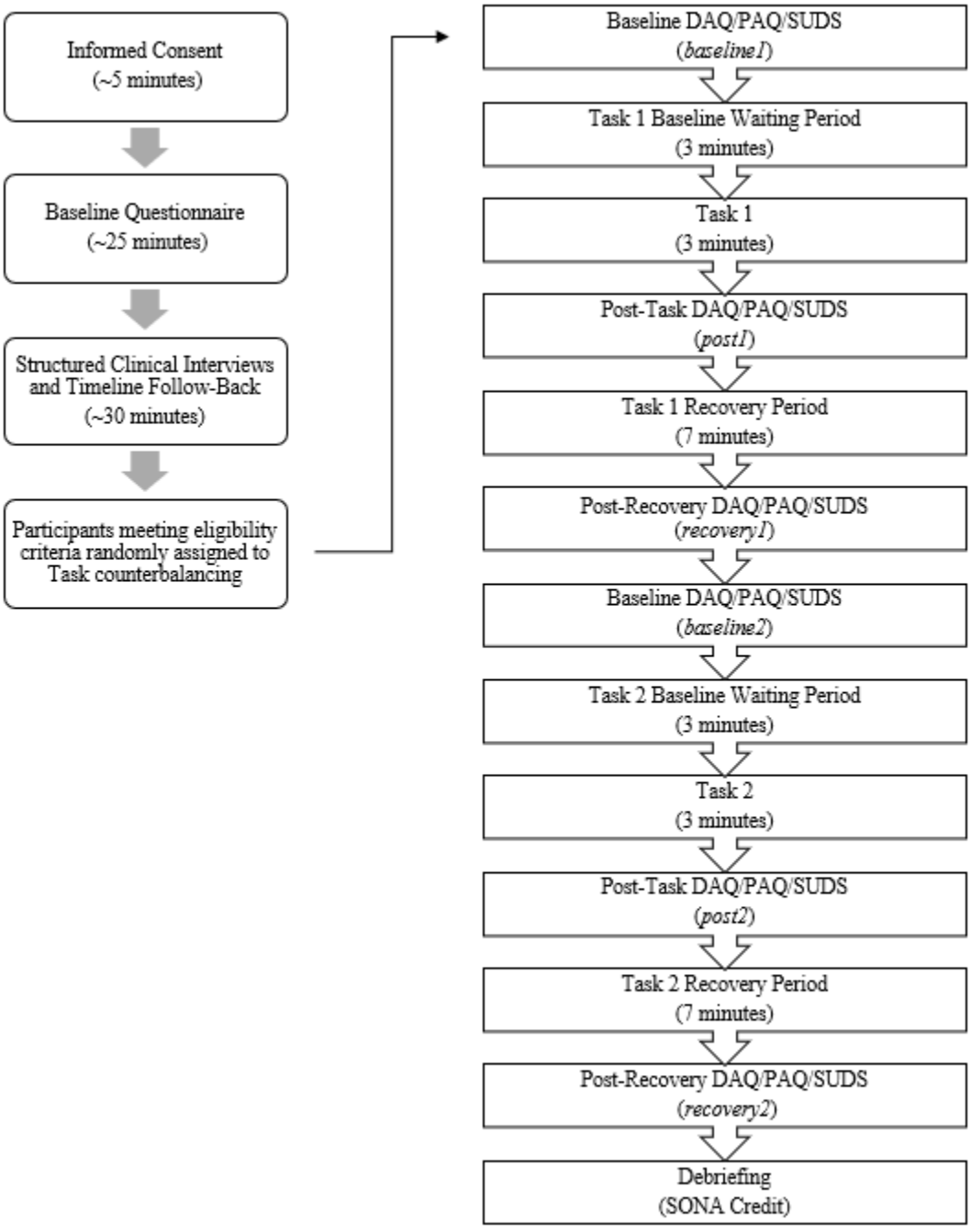

Figure 1. Procedural outline. This figure illustrates the entire procedure that participants will complete. DAQ: Desires for Alcohol Questionnaire; PAQ: items from Panic Attack Questionnaire; SUDS: Subjective Units of Distress Scale.

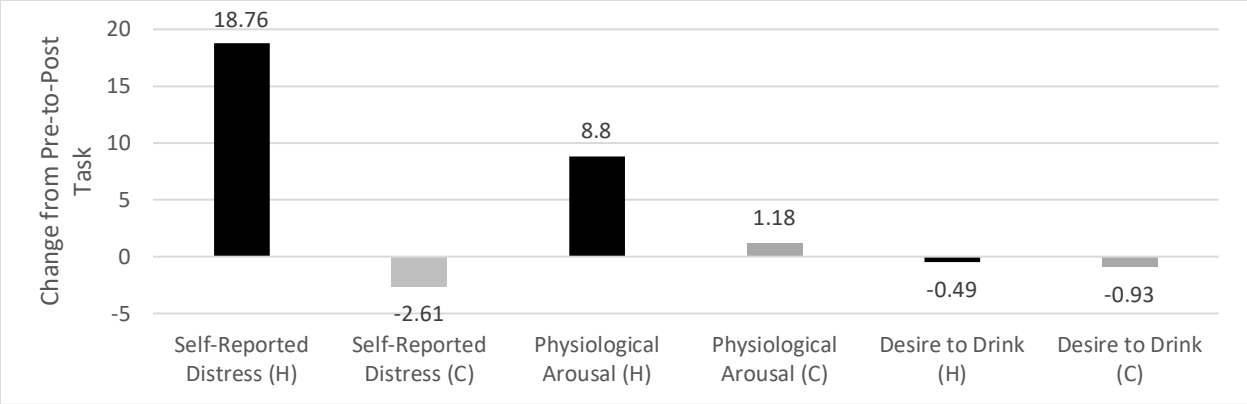

Figure 2. Change in self-reported distress, physiological arousal, and desire to drink from pre-to-post task during the voluntary hyperventilation challenge (H) and normal breathing control task (C) for overall sample (n = 80).

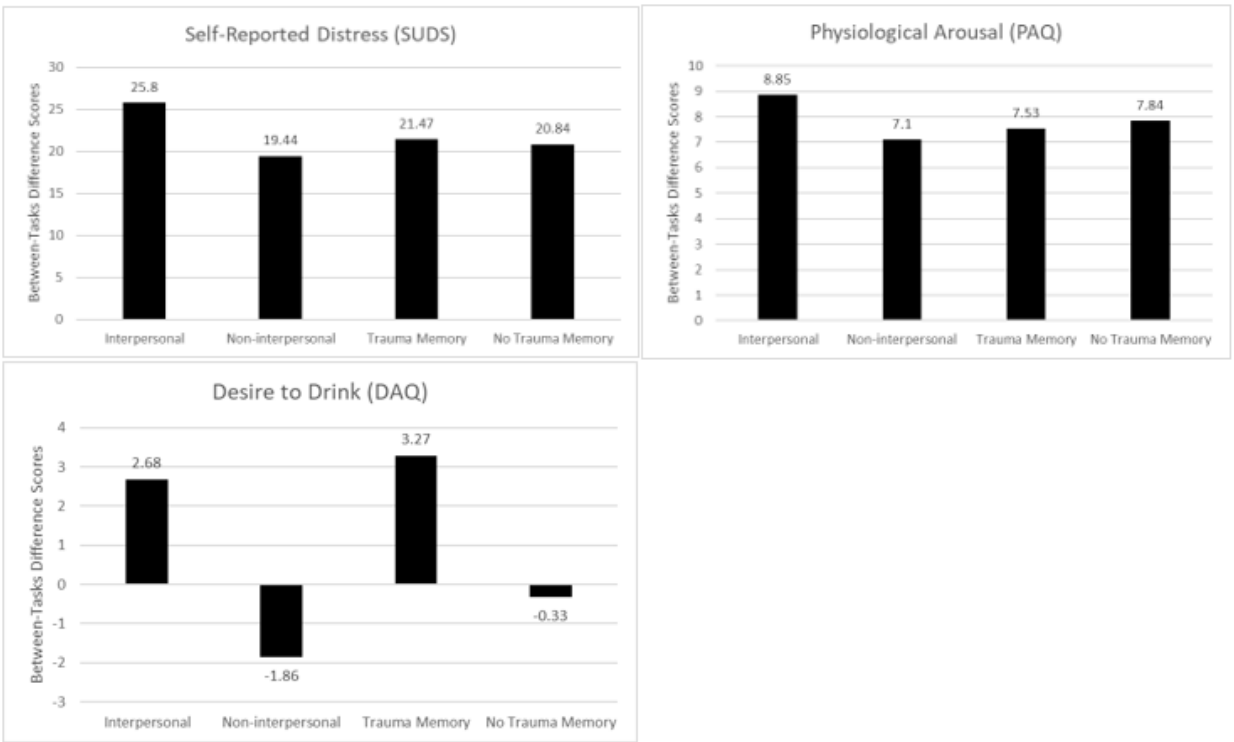

Figure 3. Comparison of between-tasks difference scores for interpersonal (n = 20) vs. non-interpersonal trauma (n = 45) and trauma memory (n = 15) vs. no trauma memory (n = 63) groups on self-reported distress, physiological arousal, and desire to drink. Note. Between-tasks difference scores: Pre-to-post task change during voluntary hyperventilation challenge minus pre-to-post change during normal breathing control task. Higher scores indicate greater positive change during the voluntary hyperventilation task, as compared to change in the normal breathing control task.

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